EXPERIMENTAL EVALUATION OF PERFORMANCE VARIABLES AND EMISSIONS FOR PRODUCER GAS–DIESEL ENGINE

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ABSTRACT: This report uncovers some of the misconceptions associated with the usage of producer gas, a lower calorific gas as a reciprocating engine fuel. This report particularly addresses the use of producer gas in reciprocating engines with the diesel. This report consists the conversion of CI engine running on dual-fuel mode. Experiments have been conducted on multi-cylinder compression ignition engine modified from a production diesel engine for different combination of producer gas and diesel over a wide range of load conditions. Performance variables considered in this work are brake power brake thermal efficiency, diesel saving and exhaust emissions i.e. carbon monoxide, nitrogen oxide and smoke density. This study also includes the economical feasibility of producer gas engines after investigating the performance variables considered in this work are optimum.
Keywords: producer gas, dual-fuel engine, exhausts emissions

I. INTRODUCTION

Producer gas-diesel dual fuel engine is one that use both conventional diesel and gaseous fuels. Diesel engine with minor modification can be made to operate on dual fuels efficiently. Dual-fuel CI engines introduce a premixed air-gaseous fuel mixture, which is ignited at the final stage of the compression stroke by a liquid fuel injection called pilot fuel. Gasification is one such process where clean gas could be generated using a wide variety of bio-residues as the feed stock and in turn use the fuel gas for power generation purposes. These are being used in standard diesel engines in dual-fuel mode of operation so as to obtain diesel savings up to 85%. Development of gas engines using producer gas has been explored ever since World War II. A well researched, tested and an industrially proven gasifier system capable of generating consistent quality was employed as the gas generator for testing purpose. Coal, wood and charcoal gasifiers have been used for operation of internal combustion engines in various applications since the beginning of this century. In industrialized countries internal combustion engines are mainly used for vehicles. Electricity generated in large central power stations is used for most of the stationary applications. These different structures of energy systems explain why there appears to be fairly small interest in using biomass gasifiers for operation of internal combustion engines in the industrialized world, whereas several developing countries are either introducing small biomass gasifiers or are in the process of evaluating the technology.[2]

II. EXPERIMENTAL TEST SETUP

A. Experimental Procedure

A diesel engine experimental setup was installed to conduct the experiment on dual-fuel engine. A Kirloskar make, four-stroke CI engine, direct injection, water cooled and gen-set was used for the experimental investigations. A downdraft gasifier was used for the generation of producer gas using rice husk. This gas is directly inducted in the intake manifold through the valve for the controlling of its supply. The engine was coupled to a 62.5 kW generator. The loading on the engine was varied by welding machine and water pump. The engine was run at a constant speed of 1500 rpm. Detailed specification of the gasifier and engine used during experimentation is given in the table. 1 & 2 respectively.

Table.1 Producer gas gasifier specification

Type of gasifier	Downdraft gasifier
Rated capacity	Urja-80
Rated gas flow (m^3/hr)	200
Rated biomass consumption	80-90 kg
Feeding	Manual
Fuel consumption	85 kg/h
Hopper capacity	300 kg approximately rice husk
Moisture content	5-20 %
Gas cooling medium	Water
Average calorific value (kcal/m^3)	1000
Typical conversion efficiency	70 %

Fig.1 view of biomass gasifier

The rice husk was fed to the gasifier through its top opening called hopper. Air enters in the combustion zone and producer gas and producer gas generated leaves near the bottom of the gasifier at the temperature of about 400-600.

The hot producer gas allows cooling by passing through the water cooler where its temperature was reduced to 50-70. The cooled gas with moisture was then passed through through the filter to remove tar and other particles. A valve was provided at the outlet of filter pipe to control the gas flow. The producer gas and air were mixed in the intake manifold and mixture enters into the engine. The increase in the gas flow rate decreases the air flow rate to the intake, as the ratio of air and gas flow rate almost remains constant. For different gas-air ratios, performance and emission tests were carried out for various load conditions. The schematic of experimental setup shown in fig.2

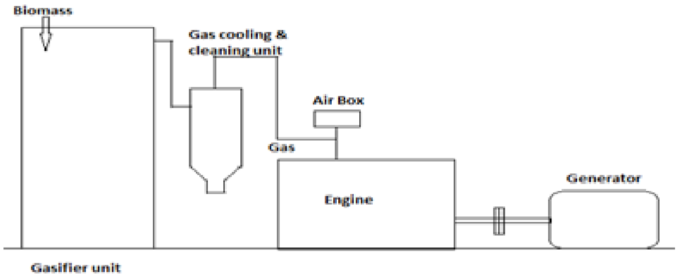


Fig.2 Schematic of experimental setup

Table.2 Engine specification

S. No.	Parameters	Engine specification
1.	Make	Kirloskar
2.	General details	Four stroke, water cooled, compressed ignition, direct injection, vertical, gen-set
3.	No. of cylinders	4
4.	Bore	100
5.	Stroke	120
6.	Speed (rpm)	1500
7.	Compression ratio	18:1
8.	Rated power in kW at 1500 rpm	62.5

III. PERFORMANCE PARAMETERS

The engine-alternator system is characterized for its performance by the following:

- Brake thermal efficiency
- Diesel saving
- Exhaust emissions
- Smoke density

A. Brake thermal Efficiency:

Brake thermal efficiency is the ratio of brake power developed by the engine to the input fuel energy.

For diesel engine:

$$\eta th = \frac{B.P.}{mf \times C.V.f} \times 100$$

For dual-fuel engine:

$$\eta th = \frac{B.P.}{mf \times C.V.f + mg \times C.V.g} \times 100$$

Where, mf and mg are the mass flow rate of diesel and producer gas, respectively, c.v.f and c.v.g are the lower heat of combustion of diesel and producer gas, repectively.

B. Diesel saving:

The diesel saving means the quantity of diesel which is substituted by producer gas during the experiment. Diesel saving is calculated by the following equation:

$$\text{Diesel saving} = \frac{mass\ of\ diesel - mass\ of\ diesel\ in\ dual\ mode}{mass\ of\ diesel} \times 100$$

C. Exhaust emissions

From the point of view of pollution control, measurement of emissions from engines is very important. Emissions may be divided into two groups, viz., invisible emissions and visible emissions. CO occurs only in engine exhaust. It is a product of incomplete combustion due to insufficient amount of air in the air- fuel mixture or insufficient time in the cycle for completion of combustion. Oxides of nitrogen which occur only in the engine exhaust are a combination of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitrogen and oxygen react at relatively high temperatures. Therefore, high temperatures and availability of oxygen are the two main reasons for the formation of NO_x. when the proper amount of oxygen is available, the higher the peak combustion temperature the more is the NO formed. Exhaust emissions i.e. CO/NO_x are measured by an exhaust gas analyzer at all loads and different values of producer gas.

D. Smoke density

The smoke of the engine exhaust is a visible indicator of the combustion process in the engine. Visible emissions are more irritating and cause nuisance. Especially in diesel engine, smoke is one of the visible emissions. Smoke is due to incomplete combustion. The smoke is measured by comparison method or by obscuration method.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Table.4 shows the performance parameters obtained in the experiments. The factors considered in the present work were gas flow percentage and load. The selection of these two factors has been made to study the effect of various producer gas-diesel combinations on the performance variables at different load conditions. The selected performance variables were brake thermal efficiency in (%), carbon monoxide (CO), oxide of nitrogen (NOx) in g/kWh and smoke density was calculated.

Table.4 Results of experiments

Exp. No.	PG (%)	Load	η_{th} (%)	CO (g/kWh)	NO_x (g/kWh)
1	00	40	27.5	0.23	6.13
2	10	40	23.0	0.29	3.64
3	20	40	24.6	0.32	3.11
4	30	40	24.7	0.37	2.35
5	40	40	24.0	0.46	2.12

6	50	40	23.5	0.51	1.88
7	70	40	23.7	0.60	1.64
8	00	60	29.7	0.29	6.60
9	10	60	25.4	0.33	5.15
10	20	60	26.5	0.34	5.00
11	30	60	27.7	0.41	4.70
12	40	60	27.0	0.47	4.31
13	50	60	26.8	0.53	3.72
14	70	60	27.2	0.62	3.40
15	00	80	31.4	0.31	9.20
16	10	80	28.0	0.33	5.24
17	20	80	28.7	0.35	5.33
18	30	80	29.2	0.42	4.86
19	40	80	28.3	0.47	4.50
20	50	80	27.6	0.52	3.94
21	70	80	28.4	0.61	3.31

A. Brake Thermal efficiency

The brake thermal efficiency is decreased during all tests performed on producer gas –diesel dual fuel

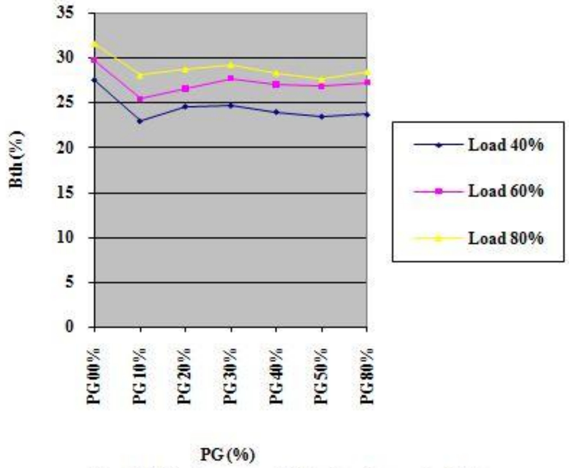


Fig. 5.1 Producer gas Vs Brake thermal efficiency

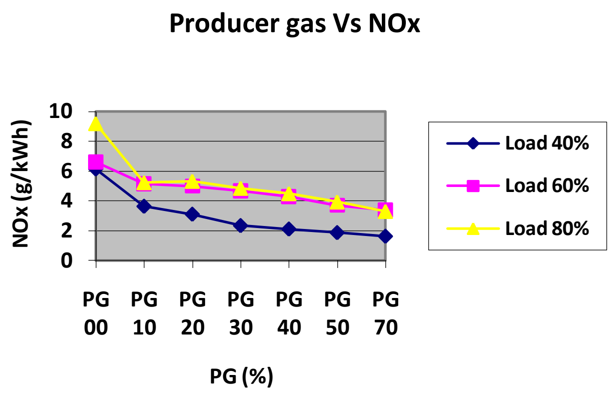
engine at all combination of producer gas and load. The optimum results of brake thermal efficiency at 30 % of producer gas on all loads. The maximum optimum brake thermal efficiency is 29.2 % on 30% gas combination and 80% load.

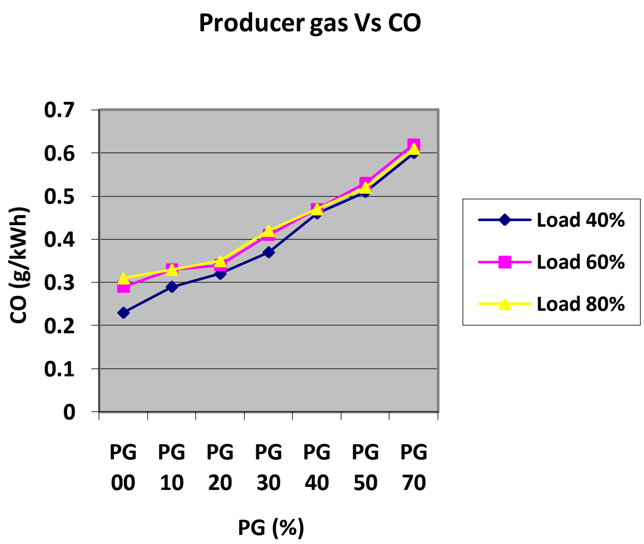
B. Diesel saving

The diesel saving in dual fuel mode operation reduces the consumption of diesel fuel at all engine loads. The maximum diesel saving is 70%. The diesel saving was increased at higher gas quantity. This phenomenon was due to the mixture being leaner at low diesel fuel.

C. Exhaust emissions

NO_x emissions for all type of fuel combinations in dual fuel mode are found to be lower than single diesel fuel engines.





CO emissions for all type of combinations in dual fuel mode are found to be more than pure diesel fuel engine operation.

D. Smoke density

Smoke density for all type of fuel combinations in dual fuel mode is found to be lower than the single diesel fuel engines. This is due to the better combustion of fuel.

V. CONCLUTIONS

In the present study the experimental analysis of producer gas–diesel engine is done. Some important findings on the engine performance and environmental aspects of electric power generation in dual fuel mode of operation while using rice husk as fuel in the gasifier are highlighted. This study proved that the diesel engine is capable of successful running in dual fuel mode of operation with the rice husk biomass in the gasifier. Based on the results, the following conclusions are drawn.

- The experimental analysis of CI engine operated on diesel and producer gas in dual-fuel mode shows that there is no major modification required in an existing diesel engine.

- The use of producer gas reduces brake thermal efficiency for all combinations of diesel-producer gas under all load conditions. However it gives satisfactory results at 30 % use of producer gas in comparison with the neat diesel while we can use maximum % of producer gas about 80. Further increase in the % of producer gas first decreases the brake thermal efficiency and then engine stop.
- The exhaust gas temperature and emissions CO for all type of fuel combinations in the dual fuel mode are found to be more than pure diesel fuel engine operations.
- The exhaust emissions NOx and smoke density for all type of the fuel combinations in dual-fuel mode are found to be lower than single diesel fuel engines.
- The low-cost/waste biomass feed stoke is used for producer gas generation. Hence, the power generation cost while using biomass is much cheaper than the conventional power cost. The captive power generation plant can be installed depending upon the availability of local biomass.

Future technology options

Technology for hydrogen rich producer gas generation can increase the scope of investment and large scale adoption of biomass gasifier based power plants.

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